On enforcing network slicing in the new generation of radio access network

1. Context

Network slicing is a new paradigm that appears with 5G to ease the deployment of different novel network services and accommodate their heterogenous requirements in terms of Quality of Service (QoS). Network Slicing relies on network softwarization through Software Defined Networking (SDN) and Network Function Virtualization (NFV), to share a common infrastructure, and build a virtualized network (or network slice) tailored to the need of network services or applications. Three main service classes of network slicing have been defined by the researchers as follows [1][2]: Enhanced Mobile Broadband (eMBB), massive Machine Type Communication (mMTC), and Ultra-Reliable and Low-Latency Communication (URLLC). A Network Slice or end-to-end network slice is composed of sub-slices (virtual or physical resources) that belong to the different technological domains [3], i.e., RAN, Core Network, Data Center domain, and instantiated on demand.

Although it is simple to isolate and slice computing and network resources for the core network (CN) elements, the Radio Access Network (RAN) presents a significant challenge. Besides, it is essential to introduce flexibility and greater utilization of network resources by providing only the necessary network resources to meet the activated slices requirements and guarantee optimal radio resource usage.

Several works [2][3][4] have addressed the challenges of enforcing network slicing at the RAN in the context of 4G, but a few discussed the case of 5G. Indeed, 5G New Radio (NR) [5] introduces several new mechanisms to improve the physical efficiency to meet the requirement of high data rate and low-latency communication, such as bandwidth part and physical numerology, which can be combined to further separate the network slices at the RAN. This thesis aims to study and propose new mechanisms and solutions to enforce network slicing in 5G and beyond networks.

2. Challenges:

During the PhD project, several challenges need to be addressed, mainly to enforce network slicing at the RAN in 5G and beyond. These challenges cover all the phases of the life cycle management of a network slice: creation, instantiation, real-time management. Among the envisioned challenges, we can mention the following:

RAN resources slicing: As indicated earlier, in 5G NR, new physical layer mechanisms have been introduced, such as bandwidth part and physical numerology. These two parameters can be combined to create RAN resources that either target high data rates or low-latency, which can be used to enforce and isolate network slices. In this context, it is important to study how these two parameters' optimal values can be derived to satisfy a network slice requirements (i.e., Bandwidth, latency, reliability, etc.). Therefore, novel mechanisms need to be specified and evaluated to derive for each type of network slice its corresponding bandwidth part and physical layer numerology.

Admission control: Admission control is an important mechanism when it comes to share limited resources among network slices. On one hand, it is important to maximize the usage of network resources; on the other hand, it is crucial when admitting a new slice to guarantee its requirements in terms of Quality of Service (QoS). Therefore, there is a need to define policies to find a trade-off between these two objectives. These policies should be based on formal studies, where solutions relying on Markov Decision Process (MDP) and Reinforcement learning need to be investigated and evaluated.

Dynamic management of RAN resources for Network slice: Once admitted into the network, it is essential to have dynamic management procedures that share the physical radio resources among the running network slices. Indeed, it is crucial to keep fairness between network slices belonging to the same type, while guaranteeing more resources to network slices with higher priority. In this context, solutions using Reinforcement Learning theory can be investigated and used to build efficient resources management solutions.

3. Organization

The PhD project is divided into three phases:

- The first phase, from M0 to M6, will be dedicated to related work on 5G, Network Slicing, RAN, and Management of radio resources. It will allow capturing the challenges related to the Network slicing in 5G RAN.
- The second phase, from M6 to M30, will consist of devising algorithms and mechanisms to address the challenges cited earlier and mainly exploring techniques based on Reinforcement Learning. The proposed solutions need first evaluated via computer simulation, but some contributions will be selected and evaluated via a proof of concept (PoC). The latter will rely on open-source tools such as OpenAirInterface (OAI) and FlexRAN 5G.
- The last phase, from M30 to M36, will be dedicated to the PhD document and the preparation of the final defense.

For the dissemination activities, we aim to publish and demonstrate the devised works in peer-reviewed conferences, such as IEEE ICC, Globecom, and Infocom. During the final year, one or two publications will be submitted to peer-reviewed journals.

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